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OSC 1183
~~COR 1037~~
COPY 1 OF 2

Memo for Record

Copy No. 15

Ser. No. CPS-302

Sheets 9

9 September 1960

25X1A

From: [redacted]

Subject: Twisting Slit IMC

This memo gives a tentative solution to the problem of obtaining image motion compensation by twisting the image, or more commonly referred as twisting the slit. The results are not final. Since this work was done the convergence angle was changed from 9° to 7.2°. However, the method for obtaining IMC is described and the resulting numbers give sufficient information to determine the degree of correction.

Image motion compensation in this type of system is maintained by driving the film at the proper rate and the proper direction to compensate for both the sweep motion of the camera and the apparent object motion due to velocity of the vehicle. During a portion of each cycle the film is driven at a constant rate and the mirror is driven at a rate which is very nearly constant. The direction of motion of the image as a result of both sweep and vehicle motion is adjusted optically to be in the same direction as the film motion. By this means, exact image motion compensation exists at one point within the lens field and along a line throughout the entire sweep. There are errors at the edge of the lens field which will be described later.

Figure 1 illustrates a system in which the camera, which is tilted forward, is sweeping across the line of sight. This represents one half of the convergent-stereo, panoramic system. With respect to the earth coordinance system, the vehicle is moving forward at a velocity V_e, at an altitude H above the nadir. The convergence angle or forward angle is Θ. The panoramic camera sweeps at a rate $\dot{\varphi}$ so that the axis of the lens appears to move toward negative y at velocity V_s. For simplicity, and to maintain a constant convergence angle independent of sweep, vector $\dot{\varphi}$ lies in the x-z plane and is tilted upward at an angle Θ. Therefore, aside from vehicle motion, the camera sees the object move at a velocity $-V_s$ as indicated in the drawing. In addition to this, the earth moves backward at an apparent velocity V_e. These two vectors, V_e and $-V_s$, combine as shown in the diagram and represent the object motion as seen by the camera. $V_e - V_s$ is projected into image space as $V_e' - V_s'$. This determines the direction and magnitude of the film velocity for perfect image motion compensation. As $\dot{\varphi}$ changes, $-V_s$ changes and the image velocity also changes. Therefore, there is a continuous change both in magnitude and direction of the image velocity. The direction can be adjusted by rotating a set of three mirrors equivalent in effect

Approved For Release 2002/10/16 : CIA-RDP67B00511R000100140066-4

Approved For Release 2002/10/16 : CIA-RDP67B00511R000100140066-4

to a dove prism. The change in magnitude must be adjusted by varying $\dot{\varphi}_i$. For ease of calculation $\dot{\varphi}$ will be assumed to be constant at first and the correction in $\dot{\varphi}$ will be made at some later point.

A similar diagram can be drawn for images at the edge of the field. Unfortunately, the image velocity at the edge of the field differs from that at the center. But the system can be optimized by making the compensation exact at the center and by accepting whatever errors exist elsewhere.

The first approximate solution was calculated for the following set of numbers.

$$\dot{\varphi} = 700 \frac{V}{H} \text{ (°/sec)}$$

$$\frac{V}{H} = .0344$$

$$\Theta = 9°$$

Since these calculations were made the average $\frac{V}{H}$ has been increased to .03½. However, the camera, which runs on an autocycle principle, can be speeded up in proportion to $\frac{V}{H}$. As a result the average values of image smear are about 2% too low but all of the velocities are correct relative to each other. The equations which apply to this system were derived by Don Smith and are on file. Further work is necessary to convert from constant sweep rate to constant film velocity.

Film drive speed and direction are given in Figure 2 for $\gamma = 0$, i.e. on axis. There is approximately a 1% change in speed and a 2½° change in direction. Figures 3 and 4 give the direction and magnitude of the film velocity at $\gamma = \pm 10°$ and $-10°$ respectively. Assuming that the sweep rate and the direction of image motion are controlled to give 100% correction for $\gamma = 0$, the important information is the velocity difference with respect to the velocity at $\gamma = 0$. These differences in magnitude and direction are given in Figure 5 and are converted to image smear for 1/100 second exposure time in Figure 6. Notice that the smear tolerance for the assumed resolution at ±10° is exceeded by the smear errors over much of the sweep range. However, the abundant overlap produced by the two cameras within the range of ±30° sweep angle makes it relatively unimportant that the tolerance is exceeded at the edge of the field. Just beyond 30° sweep angle the overlap is 52% and the edges of the field become very important for complete stereo coverage. But the overlap is such that the better portion of one frame overlaps the poorer portion of the successive frame. In this way, every object will be photographed on at least one frame within 5° of the lens axis where the amount of smear considerably less than at 10°. At very large sweep angles the overlap again becomes much greater than 50% and the edges of the field are relatively unimportant.

Approved For Release 2002/10/16 : CIA-RDP67B00511R000100140066-4

Approved For Release 2002/10/16 : CIA-RDP67B00511R000100140066-4

If an approximate solution is sufficient, the calculations can be converted very simply from constant sweep rate to constant film drive speed. The film velocity is a function of φ and vehicle velocity V_e. Since φ is adjustable by camming the sweep mirror drive but V_e is constant, φ cannot be scaled exactly in proportion to the film velocity to remove the variation in film velocity given in Figure 2. In effect, changing φ in proportion to the film velocity assumes that V_e is also changed in the same proportion. Therefore, the maximum change in φ and film velocity involves 0.6% maximum error in IMC for forward motion. Table I gives the variation in φ with sweep angle and the resultant IMC error at the center of the field.

Further calculations will be made based on a new convergence angle and a more accurate conversion from constant sweep rate to constant film velocity.

Film velocity = 8.8538"/sec. for V/H = .0344

	63°	45°	33°	16½°	0°	-30°
(rad/sec)	.41918	.41830	.41825	.41894	.42027	.42290
	-.0026	-.0047	-.0048	-.0032	0	+.0063
% IMC error	-0.26	-0.47	-0.48	-0.32	0	0.63

Table I

25X1A

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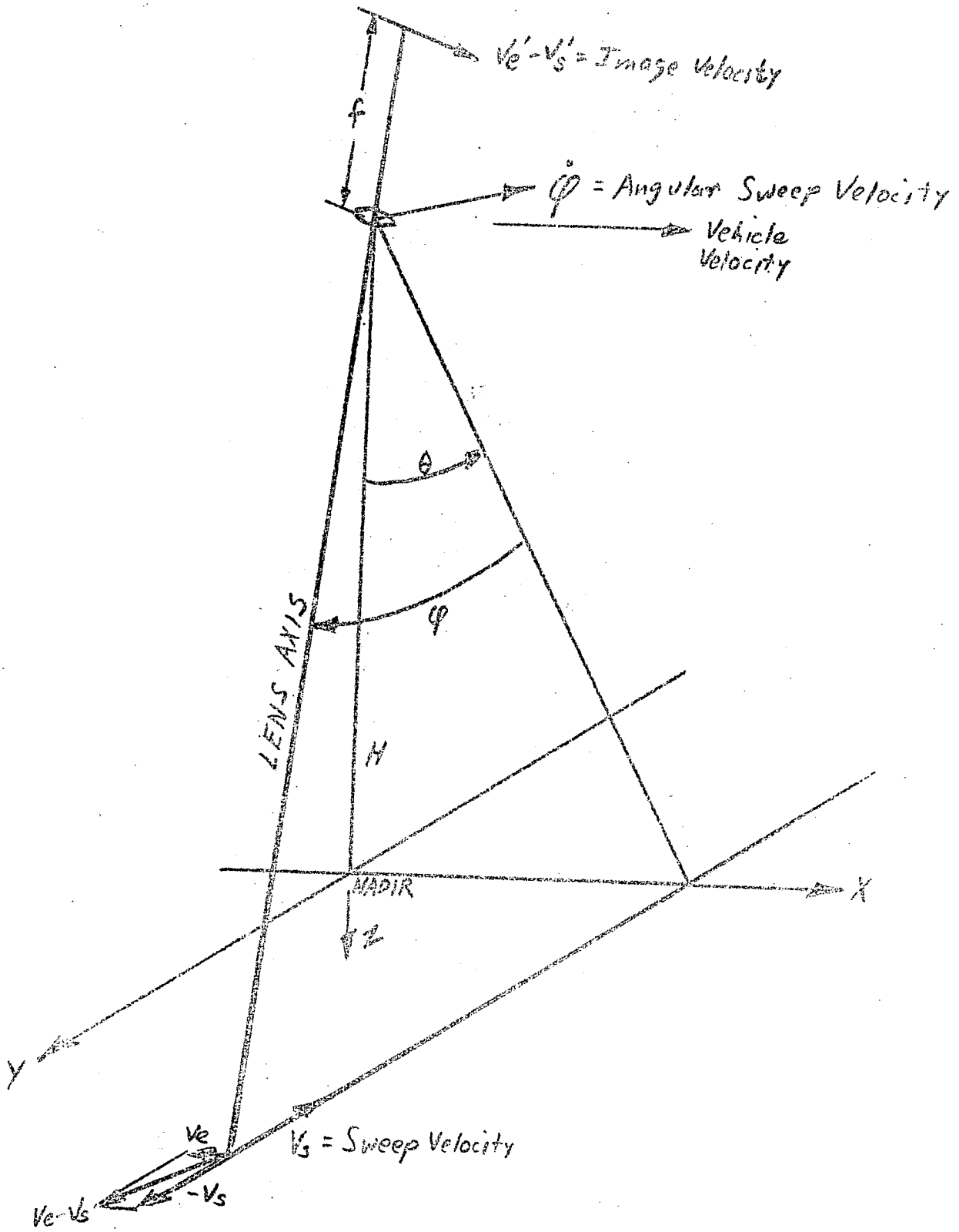
Approved For Release 2002/10/16 : CIA-RDP67B00511R000100140066-4

FIGURE 1



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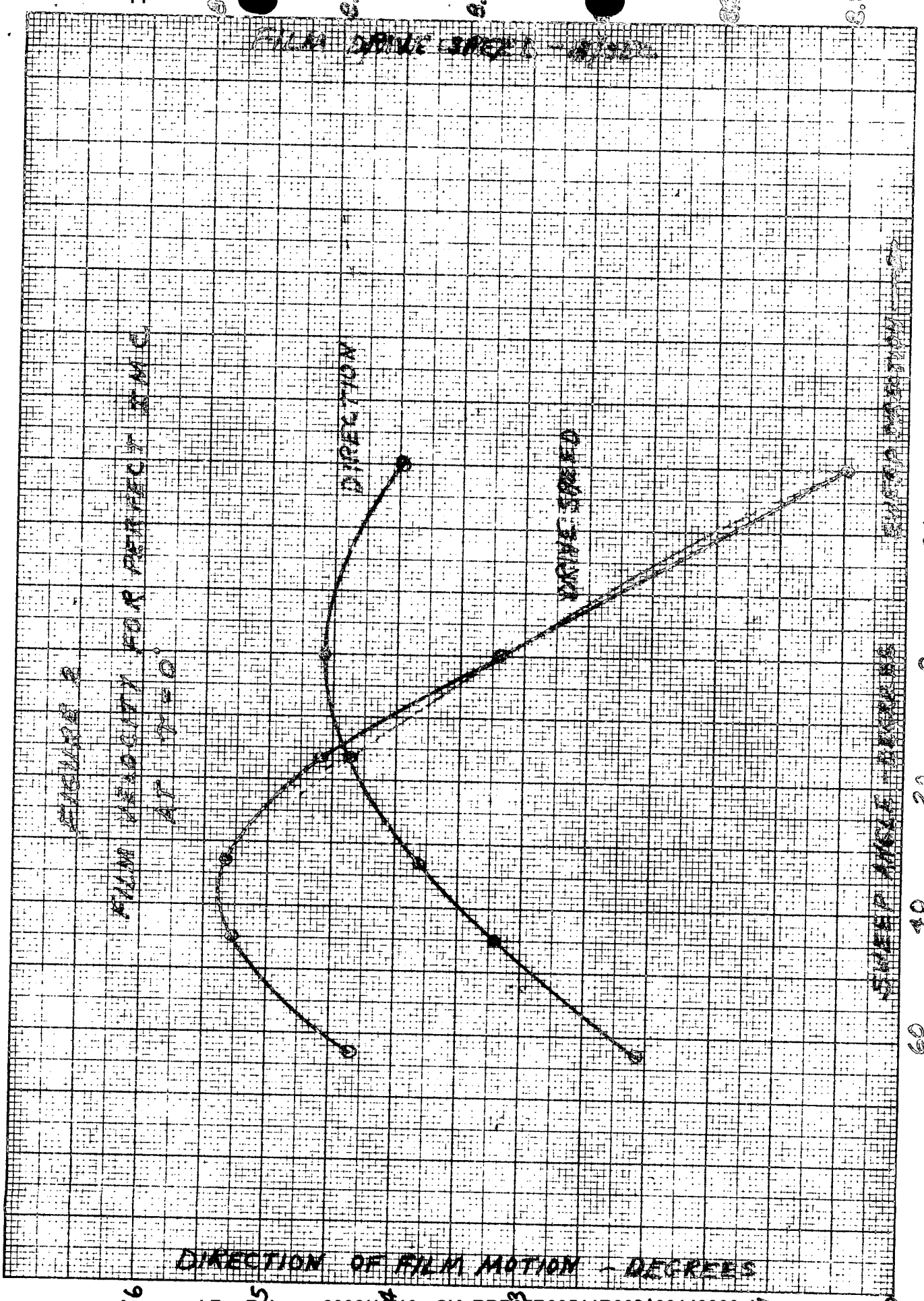

CFS-302

9 September 1960

K&E 10 X 10 TO THE INCH 359-11G KEUFFEL & ESSER CO MADE IN U.S.A.

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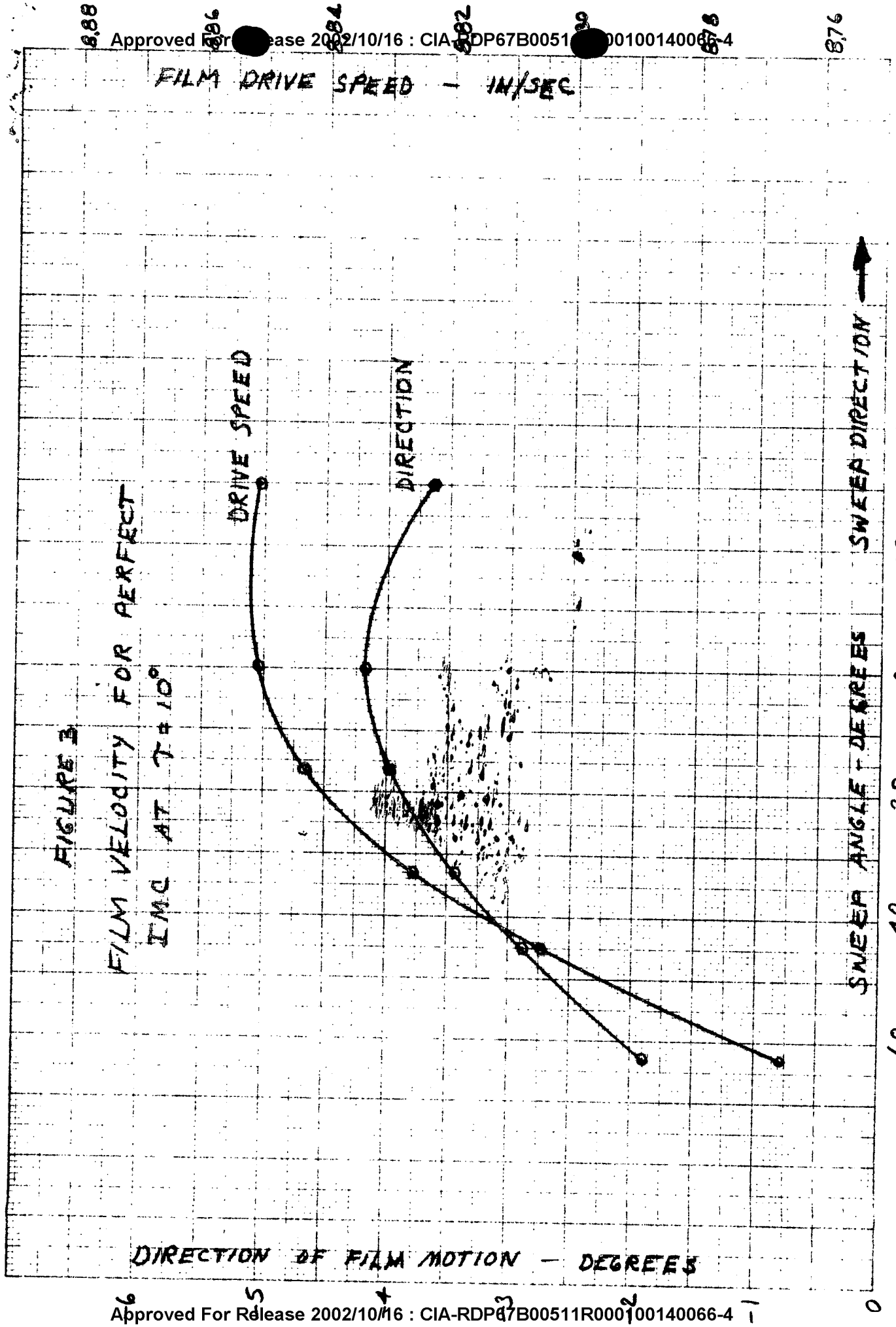


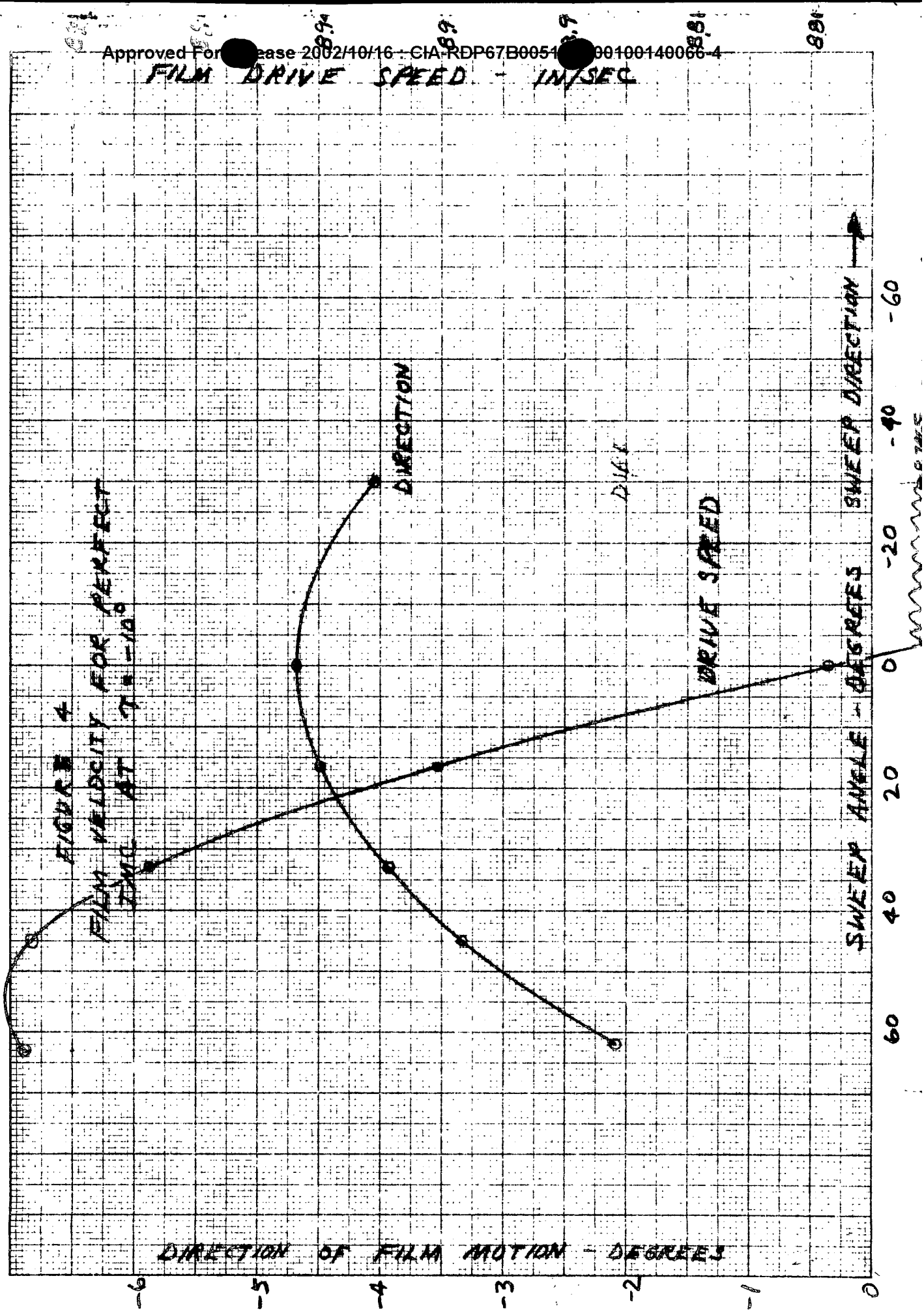
FIGURE 3
FILM VELOCITY FOR PERFECT IMC AT T = 10°

CPS-302
9 September 1960

Approved For Release 2002/10/16 : CIA-RDP67B00511R000100140066-4

Approved For Release 2002/10/16 : CIA-RDP67B00511R000100140066-4

CPS-332



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CPS-302

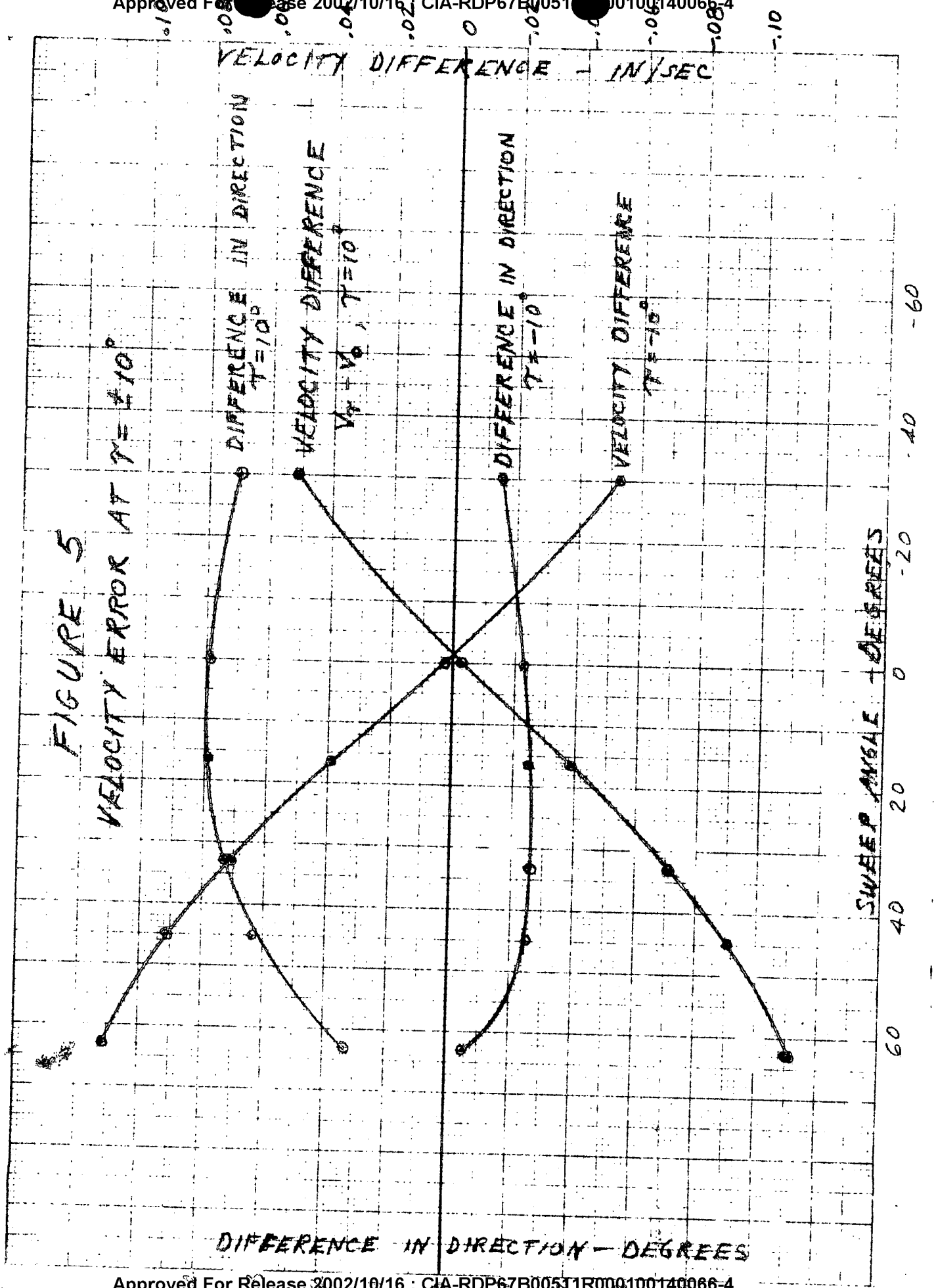


FIGURE 5
VELOCITY ERROR AT $\gamma = \pm 10°$

9 September 1960

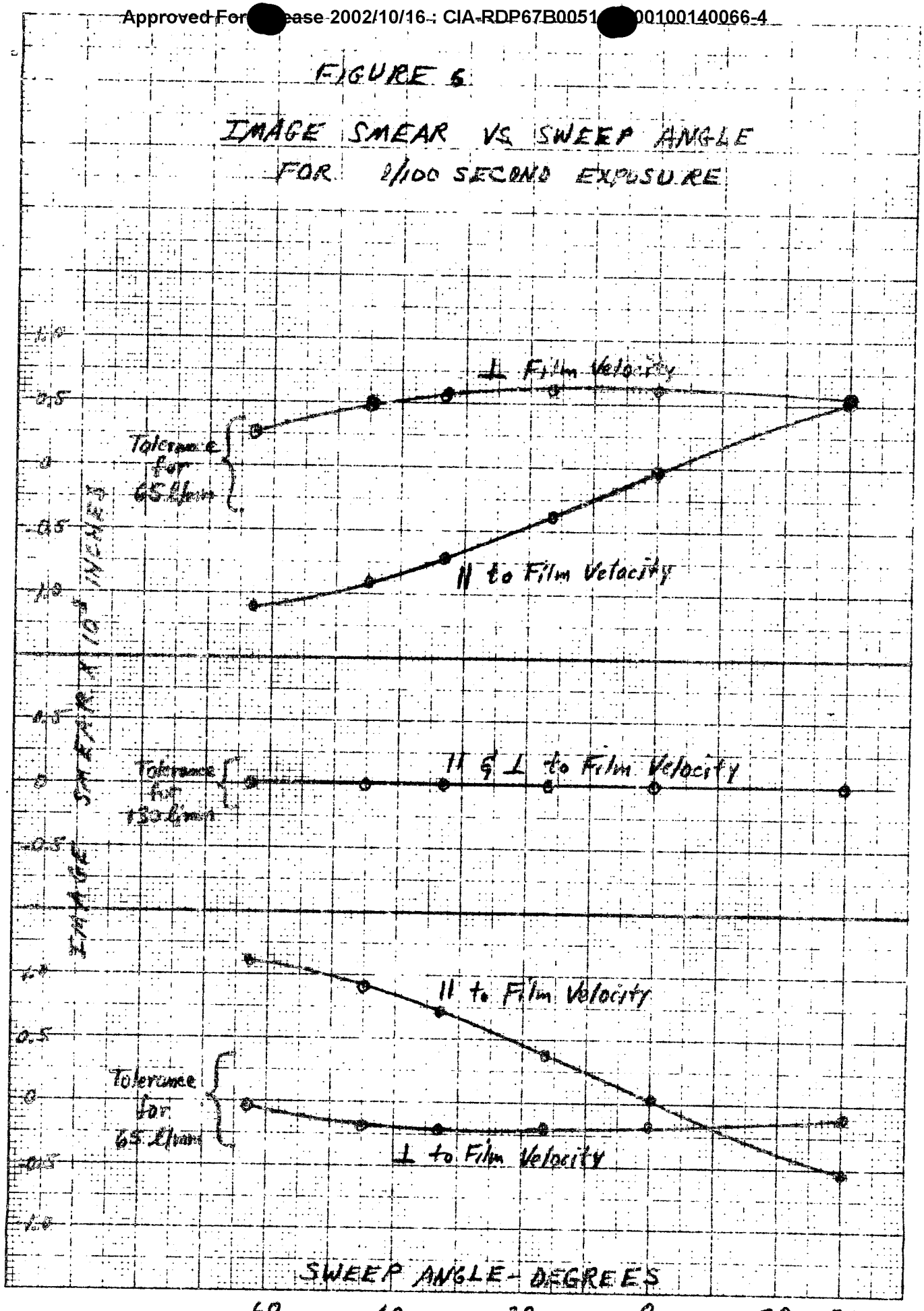
Approved For Release 2002/10/16 : CIA-RDP67B00511R000100140066-4

Approved For Release 2002/10/16 : CIA-RDP67B00511R000100140066-4

CPS-342

FIGURE 6

IMAGE SMEAR VS SWEEP ANGLE FOR 1/100 SECOND EXPOSURE



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